Army Research Laboratory

Conducting an Analysis of a Qualitative Dataset Using the Waikato Environment for Knowledge Analysis (WEKA)

by Robert A Sottilare

ARL-TR-7182 **February 2015**

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ARL-TR-7182 **February 2015**

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
February 2015

2. REPORT TYPE
Final

3. DATES COVERED (From - To)
November 2014–December 2014

4. TITLE AND SUBTITLE
Conducting an Analysis of a Qualitative Dataset Using the Waikato Environment for Knowledge Analysis (WEKA)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Robert A Sottilare

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Research Laboratory
ATTN: RDRL-HRT-T
Orlando, FL 32826

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-7182

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The purpose of this technical report is to provide an exemplar for conducting an analysis of a qualitative dataset using machine learning techniques. Qualitative data are measured or expressed as a natural language description (e.g., category or attribute) rather than numbers as in quantitative datasets. It is often difficult to evaluate the relationship between qualitative variables of interest and outcomes (dependent variables), but machine learning techniques offer simplified methods to classify these outcomes. WEKA, the Waikato Environment for Knowledge Analysis, is a popular set of machine learning algorithms developed at the University of Waikato in New Zealand, which can be used to analyze both qualitative and quantitative data. To illustrate the use of WEKA on a qualitative dataset, we selected a known set of primate species with the desire to classify them into 1 of 3 classes (prosimians, monkeys, and apes) based on 7 qualitative attributes. When an existing dataset is used with known relationships, it allows us to evaluate a large number of WEKA algorithms in a relatively short time and validate their accuracy with the goal of identifying best practices for analyzing qualitative data.

15. SUBJECT TERMS
machine learning techniques, qualitative datasets, machine learning classifiers, validation, data mining

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Robert A Sottilare
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (*Include area code*)
Unclassified	Unclassified	Unclassified	UU	62	(407) 208-3007

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

List of Tables

1. Introduction

The purpose of this technical report is to provide an exemplar for conducting an analysis of a qualitative dataset using machine learning techniques. Qualitative data are measured or expressed as a natural language description (e.g., category or attribute) rather than numbers as in quantitative datasets. It is often difficult to evaluate the relationship between qualitative variables of interest and outcomes (dependent variables), but machine learning techniques offer simplified methods to classify these outcomes. WEKA, the Waikato Environment for Knowledge Analysis, is a popular set of machine learning algorithms developed at the University of Waikato in New Zealand (Witten and Frank 2005), which can be used to analyze both qualitative and quantitative data. To illustrate the use of WEKA on a qualitative dataset, we selected a known set of primate species with the desire to classify them into 1 of 3 classes (prosimians, monkeys, and apes) based on 7 qualitative attributes. When an existing dataset is used with known relationships, it allows us to evaluate a large number of WEKA algorithms in a relatively short time and validate their accuracy with the goal of identifying best practices for analyzing qualitative data.

2. Description of the Analysis Task

The task, T, was to accurately classify primates into 1 of 3 classes (prosimians, monkeys, or apes) based on 7 attributes identified through a review of zoological references (Goodman et al. 1990; McKenna and Bell 1997; Groves 2001, 2005) that indicated the major attributes and differences among the various species of the order primates. A sample of each class of the primate order is shown in Fig. 1.

Fig. 1 Primate classes: prosimians (left), monkeys (center), and apes (right)

The context of the task follows: A robot was sent to the zoo to visit the primate area and collect data on the attributes of different types of primates. WEKA 3.6 (Witten and Frank 2005) was used to analyze the 7 attributes selected and to classify each primate using several candidate machine-learning algorithms. The performance of each algorithm was then compared to determine the best classifiers for this qualitative dataset. Primates at the zoo are described by the following 7 attributes:

1. Tail attribute: 2 possible values (tail/no tail) to indicate the presence or absence of a tail.
2. Chest size attribute: 3 possible values (broad, deep, or equal) to indicate the relationship between the breadth and depth of the chest. Broad indicates the chest is broader than it is deep, deep indicates the chest is deeper than it is broad, and equal indicates that the chest is roughly the same breadth as depth.
3. Arm-leg ratio attribute: 3 possible values (shorter, longer, or equal) to indicate the relationship between the length of the arms and the length of the legs. Shorter indicates that the arms are shorter than the legs, longer indicates that the arms are longer than the legs, and equal indicates that the arms and legs are approximately the same length.
4. Size attribute: 5 possible values (very small, small, medium, large, or very large) to indicate the relative size of primates based on ranges of weight and body length.
5. Sleep habits attribute: 2 possible values (nocturnal or diurnal) to indicate the primary sleeping habits of various species of primates. Nocturnal indicates that the primate is primarily awake at night and asleep during the day; diurnal animals generally sleep at night and are awake during the day.
6. Nose attribute: 2 possible values (wet or dry) to indicate the nose and snout type. Wet indicates the primate has a wet nose and a snout; dry indicates the primate has a dry nose and no snout.
7. Nails attribute: 3 possible values (nails, claws, or both) to indicate whether the primate possesses nails on their digits, claws on their digits, or some combination of both nails and claws.

The problem for classifying each primate at the zoo may be determined by the following given information:

- Instances, X: each of the primates at the local zoo, described by the previously mentioned attributes.
- Hypotheses, H: each hypothesis is described by a conjunction of constraints on the attributes (tail, chest size, arm-leg ratio, size, sleep habits, nose, and nails). The constraints may be “?” (any value is acceptable), “0” (no value is acceptable), or a specific value as noted in the possible values of the 7 attributes listed.

- Target Concept, c***:*** PrimateType: X → (prosimian, monkey, ape).
- Training Examples, D*:* 318 training examples of 3 classes of primates were provided and are listed in Appendix A. The training examples are approximately 75% of the total sample of 423 primates.

The goal of this analysis is to determine a hypothesis, h, in H such that $h(x) = c(x)$ for all x in X. A more detailed description of the primate classifier task in terms of performance, training experience, target function, and target function representation follows.

2.1 Performance Measure, P

The performance measure, P, for each of the classifiers tested was the percentage of primates accurately identified as prosimians, monkeys, or apes during the test runs. The speed with which each classifier generated the models was also evaluated as a performance factor which might not be critical to this small dataset but will be in larger, more complex datasets (e.g., datasets with large numbers of attributes or multiple outcomes). Finally, the number of attributes required to classify a primate was evaluated as an efficiency factor where lower numbers of attributes to gain the same accuracy are desirable.

2.2 Training Experience, *E*

The examples used to train the robot to classify and identify prosimians, monkeys, and apes are listed in Appendix A. The training examples cover all the possible values for the 7 attributes selected to classify the primate species into the 3 possible outcomes (prosimians, monkeys, and apes). Approximately 24% of all primate species are prosimians. Approximately 67% of all primate species are monkeys, and approximately 9% are apes. These proportions are reflected in the training examples.

2.3 Target Function, H

For the target function, H, the valuation of each hypothesis was chosen as the indicator of the performance of the algorithms tested. If some instances, *x*, satisfied all the constraints of the hypothesis, *h,* for that outcome (i.e., monkeys), then *h*, classifies *x* as a positive example ($h(x)$ =1).

2.4 Target Function Representation, h(x)

The target function representation is in the form of rules that define the combination of attribute values needed to define each specific outcome. Since we have 3 possible outcomes (prosimians, monkeys, and apes), the expectation is that we will have a minimum of 3 rules. The rules may or may not require all attributes. For the 7 attributes evaluated, an example of a rule that classifies *x* as a positive example of ape may be

$$h(x)_{ape} = \text{(no tail,?,?,?,?,?, nails)} = 1 \; . \tag{1}$$

This hypothesis states that any primate that lacks a tail and has nails will be classified as an ape in 100% of the instances presented to the classifier model. It also indicates that no other attributes besides the tail and nails attributes influence this hypothesis.

3. Results and Discussion

Fifteen classifiers were trained using the training data in Appendix A and validated with the testing data in Appendix B. The results of each of the classifier runs are presented in Appendix C. As noted earlier, the measures to evaluate the performance of each algorithm include classifier accuracy, classifier speed, and classifier efficiency.

The classifier accuracy rates are shown in Table 1. Eleven of the 15 classifiers evaluated were 100% accurate in classifying primates for both the training data and the test data. The number of accurate classifiers indicates that the data set (attributes and values) describing the primate group are very representative of the characteristics of and differences between the 3 classes within the primate group.

Table 1 Classifier accuracy and speed

Classifier	**Training Data**		**Test Data**		**Time to Build Data (s)**
	% Correct	**% Incorrect**	**% Correct**	**% Incorrect**	
Naïve bayes classifier	100.000	0.000	100.000	0.000	<0.01
Random tree	100.000	0.000	100.000	0.000	0.01
LWL classifier	100.000	0.000	100.000	0.000	0.01
Non-nested generalized exemplars	100.000	0.000	100.000	0.000	0.02
PART decision list	100.000	0.000	100.000	0.000	0.02
Prism classifier	100.000	0.000	100.000	0.000	0.02
Bayes network classifier	100.000	0.000	100.000	0.000	0.02
RiDoR learner	100.000	0.000	100.000	0.000	0.04
JRip	100.000	0.000	100.000	0.000	0.07
Logistic function	100.000	0.000	100.000	0.000	0.26
Multilayer perceptron function	100.000	0.000	100.000	0.000	10.12
OneR classifier	91.195	8.805	91.429	8.571	0.01
Decision stump	91.195	8.805	91.429	8.571	0.01
Conjunctive rule	91.195	8.805	91.429	8.571	0.03
ZeroR classifier	67.296	32.704	67.619	32.381	0.00

Generally, the errors in the 4 less accurate classifiers were due to an insufficient number of rules to cover the all the possible outcomes. For example, the OneR Classifier generated 2 rules related to the nose attribute: 1) wet -> Prosimian and 2) dry -> Monkey. The outcome, “Apes”, is not covered by these rules. For the training data set, 290 of 318 instances were correct; over 91%. This might be considered fairly accurate, but the accuracy of the OneR Classifier for this data set is dependent on the number of apes in the sample. Since apes are not covered in the OneR Classifier model, the higher the number of instances of apes in the data set, the higher the error rate.

In reviewing the influence of each attribute on the 3 hypotheses, the attributes for tail presence, nose type, arm-leg ratio, and sleep habits appeared most often with nose type and tail presence appearing in almost every model. The attributes for nail type, size, and chest size did not seem to have as much of an influence on classification.

Time to build the model was compared (Table 1) with the thought that time and accuracy would be discerning factors in selecting the best (most efficient) model. However, the time to build a classifier model from such a small dataset was not an indicator of a well-performing model. Instead, a more representative factor in evaluating a model was the number of attributes needed to predict a class. The fewer attributes needed to classify indicated a more efficient model requiring fewer rules and thereby less processing cycles. The classifiers were ranked based on accuracy of predictions and number of attributes as shown in Table 2.

Table 2 Ranking of classifier models

Classifier	Accuracy (%)	No. of Attributes
JRip	100.000	2
Part decision list	100.000	2
RiDoR learner	100.000	3
Random tree	100.000	3
Prism classifier	100.000	4
Nonnested generalized exemplars	100.000	7
Bayes network classifier	100.000	7
Naïve bayes classifier	100.000	7
Logistic function	100.000	7
Multilayer perceptron function	100.000	7
LWL classifier	100.000	7
Conjunctive rule	91.429	1
OneR classifier	91.429	1
Decision stump	91.429	1
ZeroR classifier	67.619	0

4. Conclusions

Based on the rules/weights generated by the 15 classifiers evaluated, the following 3 most generalized hypotheses are validated for $h(x)$ = (tail, chest size, arm-leg ratio, size, sleep habits, nose, and nails):

- $h(x)_{prosimian}$ = (?, ?, ?, ?, ?, wet, ?) = 1
- $h(x)_{ape}$ = (no tail, ?, ?, ?, ?, ?, ?) = 1
- $h(x)_{monkey}$ = (tail, ?, ?, ?, ?, dry, ?) = 1

Based on the previously stated validated hypotheses, 3 rules were developed:

- IF Tails = “no tail” THEN Outcome = Ape;
- IF Nose = “wet” THEN Outcome = Prosimian;
- IF Nose = “dry” AND Tails = “tail” THEN Outcome = Monkey

In other words, these may be combined into one compound rule where all primates are monkeys unless they have no tail (in which case they are an ape) or they have a wet nose (in which case they are a prosimian). This simplified model is shown in Fig. 2. There are no primates that have no tail and a wet nose.

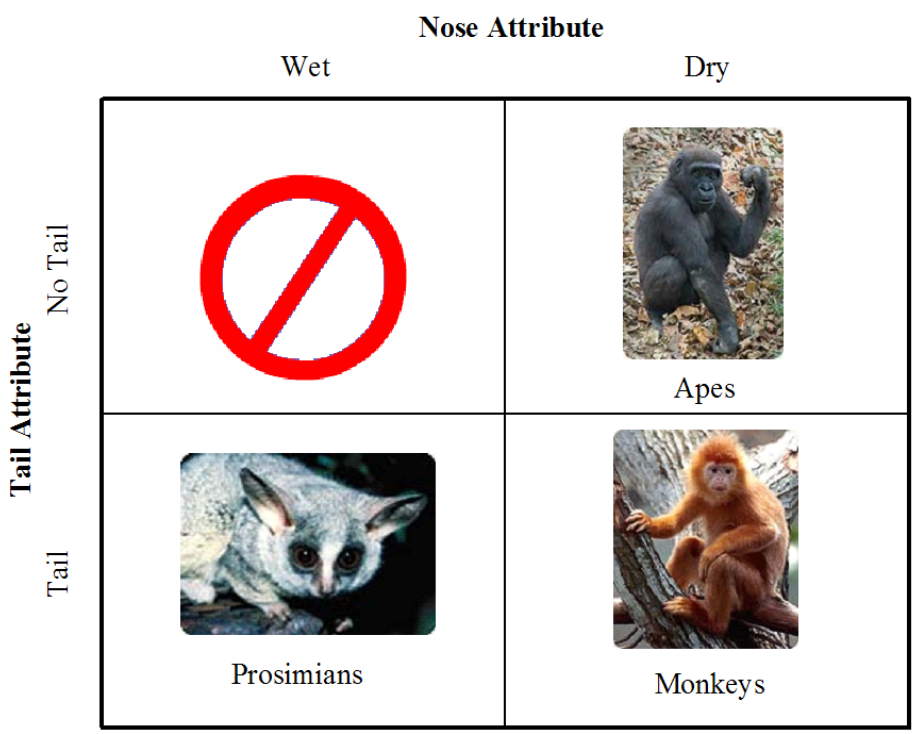

Fig. 2 Primate classifier

Only 2 (nose type and tail presence) of the 7 attributes evaluated were actually required to classify a primate. Five (size, arm-leg ratio, chest size, sleeping habits, and nail types) of the 7 attributes evaluated are unnecessary to classify primates. For classification of primates, the most accurate (percent of classifications correct) and efficient models (fewest number of attributes to define an outcome) were generated using the Java Repeated Incremental Pruning algorithm and Partial Decision List classifiers.

This technical report has illustrated methods for analyzing qualitative datasets and also shows that different methods (e.g., machine-learning algorithms) can vary in accuracy, speed, and efficiency even with the identical datasets. While scalability was not a major point of emphasis in this report, it is a factor in analyzing larger qualitative datasets where near real-time response is required (e.g., training systems).

5. References

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Appendix A. Training Examples

This appendix appears in its original form, without editorial change.

Example	Tail	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
1	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
2	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
3	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
4	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
5	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
6	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
7	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
8	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
9	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
10	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
11	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
12	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
13	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
14	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
15	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
16	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
17	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
18	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
19	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
20	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
21	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
22	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
23	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
24	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
25	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
26	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
27	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
28	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
29	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
30	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
31	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
32	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
33	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
34	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
35	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
36	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
37	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
38	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
39	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
40	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
41	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
42	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
43	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
44	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
45	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
46	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
47	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
48	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
49	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
50	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
51	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
52	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
53	tail	equal	shorter	medium	nocturnal	wet	claws and nails	Prosimian
54	tail	equal	shorter	small	diurnal	wet	claws	Prosimian
55	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian

Example	Tail	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
56	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
57	tail	deep	shorter	small	nocturnal	wet	claws and nails	Prosimian
58	tail	deep	shorter	small	nocturnal	wet	claws and nails	Prosimian
59	tail	deep	shorter	small	nocturnal	wet	claws and nails	Prosimian
60	tail	deep	shorter	small	nocturnal	wet	claws and nails	Prosimian
61	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
62	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
63	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
64	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
65	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
66	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
67	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
68	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
69	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
70	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
71	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
72	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
73	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
74	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
75	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
76	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
77	tail	deep	shorter	small	diurnal	dry	claws	Monkey
78	tail	deep	shorter	small	diurnal	dry	claws	Monkey
79	tail	deep	shorter	small	diurnal	dry	claws	Monkey
80	tail	deep	shorter	small	diurnal	dry	claws	Monkey
81	tail	deep	shorter	small	diurnal	dry	claws	Monkey
82	tail	deep	shorter	small	diurnal	dry	claws	Monkey
83	tail	deep	shorter	small	diurnal	dry	claws	Monkey
84	tail	deep	shorter	small	diurnal	dry	claws	Monkey
85	tail	deep	shorter	small	diurnal	dry	claws	Monkey
86	tail	deep	shorter	small	diurnal	dry	claws	Monkey
87	tail	deep	shorter	small	diurnal	dry	claws	Monkey
88	tail	deep	shorter	small	diurnal	dry	claws	Monkey
89	tail	deep	shorter	small	diurnal	dry	claws	Monkey
90	tail	deep	shorter	small	diurnal	dry	claws	Monkey
91	tail	deep	shorter	small	diurnal	dry	claws	Monkey
92	tail	deep	shorter	small	diurnal	dry	claws	Monkey
93	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
94	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
95	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
96	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
97	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
98	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
99	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
100	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
101	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
102	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
103	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
104	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
105	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
106	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
107	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
108	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
109	tail	deep	equal	small	diurnal	dry	nails	Monkey
110	tail	deep	equal	small	diurnal	dry	nails	Monkey
111	tail	deep	equal	small	diurnal	dry	nails	Monkey
112	tail	deep	equal	small	diurnal	dry	nails	Monkey
113	tail	deep	equal	small	diurnal	dry	nails	Monkey
114	tail	deep	equal	small	diurnal	dry	nails	Monkey
115	tail	deep	equal	medium	diurnal	dry	nails	Monkey
116	tail	deep	equal	medium	diurnal	dry	nails	Monkey
117	tail	deep	equal	medium	diurnal	dry	nails	Monkey
118	tail	deep	equal	medium	diurnal	dry	nails	Monkey
119	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey
120	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey

Example	Tail	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
121	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey
122	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey
123	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey
124	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey
125	tail	deep	equal	medium	diurnal	dry	nails	Monkey
126	tail	deep	equal	medium	diurnal	dry	nails	Monkey
127	tail	deep	equal	medium	diurnal	dry	nails	Monkey
128	tail	deep	equal	medium	diurnal	dry	nails	Monkey
129	tail	deep	equal	medium	diurnal	dry	nails	Monkey
130	tail	deep	equal	medium	diurnal	dry	nails	Monkey
131	tail	deep	equal	medium	diurnal	dry	nails	Monkey
132	tail	deep	equal	medium	diurnal	dry	nails	Monkey
133	tail	deep	equal	medium	diurnal	dry	nails	Monkey
134	tail	deep	equal	medium	diurnal	dry	nails	Monkey
135	tail	deep	equal	medium	diurnal	dry	nails	Monkey
136	tail	deep	equal	medium	diurnal	dry	nails	Monkey
137	tail	deep	equal	medium	diurnal	dry	nails	Monkey
138	tail	deep	equal	medium	diurnal	dry	nails	Monkey
139	tail	deep	equal	medium	diurnal	dry	nails	Monkey
140	tail	deep	equal	medium	diurnal	dry	nails	Monkey
141	tail	deep	equal	medium	diurnal	dry	nails	Monkey
142	tail	deep	equal	medium	diurnal	dry	nails	Monkey
143	tail	deep	equal	medium	diurnal	dry	nails	Monkey
144	tail	deep	equal	medium	diurnal	dry	nails	Monkey
145	tail	deep	equal	medium	diurnal	dry	nails	Monkey
146	tail	deep	equal	medium	diurnal	dry	nails	Monkey
147	tail	deep	equal	medium	diurnal	dry	nails	Monkey
148	tail	deep	equal	medium	diurnal	dry	nails	Monkey
149	tail	deep	equal	medium	diurnal	dry	nails	Monkey
150	tail	deep	equal	medium	diurnal	dry	nails	Monkey
151	tail	deep	equal	medium	diurnal	dry	nails	Monkey
152	tail	deep	equal	medium	diurnal	dry	nails	Monkey
153	tail	deep	equal	medium	diurnal	dry	nails	Monkey
154	tail	deep	equal	medium	diurnal	dry	nails	Monkey
155	tail	deep	equal	medium	diurnal	dry	nails	Monkey
156	tail	deep	equal	large	diurnal	dry	nails	Monkey
157	tail	deep	equal	large	diurnal	dry	nails	Monkey
158	tail	deep	equal	large	diurnal	dry	nails	Monkey
159	tail	deep	equal	large	diurnal	dry	nails	Monkey
160	tail	deep	equal	large	diurnal	dry	nails	Monkey
161	tail	deep	equal	large	diurnal	dry	nails	Monkey
162	tail	deep	equal	large	diurnal	dry	nails	Monkey
163	tail	deep	equal	large	diurnal	dry	nails	Monkey
164	tail	deep	equal	large	diurnal	dry	nails	Monkey
165	tail	deep	equal	large	diurnal	dry	nails	Monkey
166	tail	deep	equal	large	diurnal	dry	nails	Monkey
167	tail	deep	equal	medium	diurnal	dry	nails	Monkey
168	tail	deep	equal	medium	diurnal	dry	nails	Monkey
169	tail	deep	equal	medium	diurnal	dry	nails	Monkey
170	tail	deep	equal	medium	diurnal	dry	nails	Monkey
171	tail	deep	equal	medium	diurnal	dry	nails	Monkey
172	tail	deep	equal	medium	diurnal	dry	nails	Monkey
173	tail	deep	equal	medium	diurnal	dry	nails	Monkey
174	tail	deep	equal	medium	diurnal	dry	nails	Monkey
175	tail	deep	equal	medium	diurnal	dry	nails	Monkey
176	tail	deep	equal	medium	diurnal	dry	nails	Monkey
177	tail	deep	equal	medium	diurnal	dry	nails	Monkey
178	tail	deep	equal	medium	diurnal	dry	nails	Monkey
179	tail	deep	equal	medium	diurnal	dry	nails	Monkey
180	tail	deep	equal	medium	diurnal	dry	nails	Monkey
181	tail	deep	equal	medium	diurnal	dry	nails	Monkey
182	tail	deep	equal	small	diurnal	dry	nails	Monkey
183	tail	deep	equal	small	diurnal	dry	nails	Monkey
184	tail	deep	equal	medium	diurnal	dry	nails	Monkey
185	tail	deep	equal	medium	diurnal	dry	nails	Monkey

Example	Tail	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
186	tail	deep	equal	medium	diurnal	dry	nails	Monkey
187	tail	deep	equal	medium	diurnal	dry	nails	Monkey
188	tail	deep	equal	medium	diurnal	dry	nails	Monkey
189	tail	deep	equal	medium	diurnal	dry	nails	Monkey
190	tail	deep	equal	medium	diurnal	dry	nails	Monkey
191	tail	deep	equal	medium	diurnal	dry	nails	Monkey
192	tail	deep	equal	medium	diurnal	dry	nails	Monkey
193	tail	deep	equal	medium	diurnal	dry	nails	Monkey
194	tail	deep	equal	medium	diurnal	dry	nails	Monkey
195	tail	deep	equal	medium	diurnal	dry	nails	Monkey
196	tail	deep	equal	medium	diurnal	dry	nails	Monkey
197	tail	deep	equal	medium	diurnal	dry	nails	Monkey
198	tail	deep	equal	medium	diurnal	dry	nails	Monkey
199	tail	deep	equal	medium	diurnal	dry	nails	Monkey
200	tail	deep	equal	medium	diurnal	dry	nails	Monkey
201	tail	deep	equal	medium	diurnal	dry	nails	Monkey
202	tail	deep	equal	medium	diurnal	dry	nails	Monkey
203	tail	deep	equal	medium	diurnal	dry	nails	Monkey
204	tail	deep	equal	medium	diurnal	dry	nails	Monkey
205	tail	deep	equal	medium	diurnal	dry	nails	Monkey
206	tail	deep	equal	medium	diurnal	dry	nails	Monkey
207	tail	deep	equal	medium	diurnal	dry	nails	Monkey
208	tail	deep	equal	medium	diurnal	dry	nails	Monkey
209	tail	deep	equal	medium	diurnal	dry	nails	Monkey
210	tail	deep	equal	medium	diurnal	dry	nails	Monkey
211	tail	deep	equal	medium	diurnal	dry	nails	Monkey
212	tail	deep	equal	medium	diurnal	dry	nails	Monkey
213	tail	deep	equal	medium	diurnal	dry	nails	Monkey
214	tail	deep	equal	medium	diurnal	dry	nails	Monkey
215	tail	deep	equal	medium	diurnal	dry	nails	Monkey
216	tail	deep	equal	medium	diurnal	dry	nails	Monkey
217	tail	deep	equal	medium	diurnal	dry	nails	Monkey
218	tail	deep	equal	medium	diurnal	dry	nails	Monkey
219	tail	deep	equal	medium	diurnal	dry	nails	Monkey
220	tail	deep	equal	medium	diurnal	dry	nails	Monkey
221	tail	deep	equal	medium	diurnal	dry	nails	Monkey
222	tail	deep	equal	medium	diurnal	dry	nails	Monkey
223	tail	deep	equal	medium	diurnal	dry	nails	Monkey
224	tail	deep	equal	medium	diurnal	dry	nails	Monkey
225	tail	deep	equal	medium	diurnal	dry	nails	Monkey
226	tail	deep	equal	medium	diurnal	dry	nails	Monkey
227	tail	broad	equal	medium	diurnal	dry	nails	Monkey
228	tail	broad	equal	large	diurnal	dry	nails	Monkey
229	tail	broad	equal	large	diurnal	dry	nails	Monkey
230	tail	broad	equal	large	diurnal	dry	nails	Monkey
231	tail	broad	equal	large	diurnal	dry	nails	Monkey
232	tail	deep	equal	medium	diurnal	dry	nails	Monkey
233	tail	deep	equal	medium	diurnal	dry	nails	Monkey
234	tail	deep	equal	medium	diurnal	dry	nails	Monkey
235	tail	deep	equal	medium	diurnal	dry	nails	Monkey
236	tail	deep	equal	medium	diurnal	dry	nails	Monkey
237	tail	deep	equal	medium	diurnal	dry	nails	Monkey
238	tail	broad	equal	large	diurnal	dry	nails	Monkey
239	tail	broad	equal	large	diurnal	dry	nails	Monkey
240	tail	broad	equal	large	diurnal	dry	nails	Monkey
241	tail	broad	equal	large	diurnal	dry	nails	Monkey
242	tail	broad	equal	large	diurnal	dry	nails	Monkey
243	tail	broad	equal	large	diurnal	dry	nails	Monkey
244	tail	broad	equal	large	diurnal	dry	nails	Monkey
245	tail	broad	equal	large	diurnal	dry	nails	Monkey
246	tail	broad	equal	large	diurnal	dry	nails	Monkey
247	tail	broad	equal	large	diurnal	dry	nails	Monkey
248	tail	broad	equal	large	diurnal	dry	nails	Monkey
249	tail	broad	equal	large	diurnal	dry	nails	Monkey
250	tail	broad	equal	large	diurnal	dry	nails	Monkey

Example	Tail	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
251	tail	broad	equal	large	diurnal	dry	nails	Monkey
252	tail	broad	equal	large	diurnal	dry	nails	Monkey
253	tail	broad	equal	large	diurnal	dry	nails	Monkey
254	tail	broad	equal	large	diurnal	dry	nails	Monkey
255	tail	broad	equal	large	diurnal	dry	nails	Monkey
256	tail	broad	equal	large	diurnal	dry	nails	Monkey
257	tail	broad	equal	large	diurnal	dry	nails	Monkey
258	tail	deep	equal	medium	diurnal	dry	nails	Monkey
259	tail	deep	equal	medium	diurnal	dry	nails	Monkey
260	tail	deep	equal	medium	diurnal	dry	nails	Monkey
261	tail	deep	equal	medium	diurnal	dry	nails	Monkey
262	tail	deep	equal	medium	diurnal	dry	nails	Monkey
263	tail	deep	equal	medium	diurnal	dry	nails	Monkey
264	tail	deep	equal	medium	diurnal	dry	nails	Monkey
265	tail	deep	equal	medium	diurnal	dry	nails	Monkey
266	tail	deep	equal	medium	diurnal	dry	nails	Monkey
267	tail	deep	equal	medium	diurnal	dry	nails	Monkey
268	tail	deep	equal	medium	diurnal	dry	nails	Monkey
269	tail	deep	equal	medium	diurnal	dry	nails	Monkey
270	tail	deep	equal	medium	diurnal	dry	nails	Monkey
271	tail	deep	equal	medium	diurnal	dry	nails	Monkey
272	tail	deep	equal	medium	diurnal	dry	nails	Monkey
273	tail	deep	equal	medium	diurnal	dry	nails	Monkey
274	tail	deep	equal	medium	diurnal	dry	nails	Monkey
275	tail	deep	equal	medium	diurnal	dry	nails	Monkey
276	tail	deep	equal	medium	diurnal	dry	nails	Monkey
277	tail	deep	equal	medium	diurnal	dry	nails	Monkey
278	tail	deep	equal	medium	diurnal	dry	nails	Monkey
279	tail	deep	equal	medium	diurnal	dry	nails	Monkey
280	tail	deep	equal	medium	diurnal	dry	nails	Monkey
281	tail	deep	equal	medium	diurnal	dry	nails	Monkey
282	tail	deep	equal	medium	diurnal	dry	nails	Monkey
283	tail	deep	equal	medium	diurnal	dry	nails	Monkey
284	tail	deep	equal	medium	diurnal	dry	nails	Monkey
285	tail	deep	equal	medium	diurnal	dry	nails	Monkey
286	tail	deep	equal	medium	diurnal	dry	nails	Monkey
287	tail	deep	equal	medium	diurnal	dry	nails	Monkey
288	tail	deep	equal	medium	diurnal	dry	nails	Monkey
289	tail	deep	equal	medium	diurnal	dry	nails	Monkey
290	tail	deep	equal	medium	diurnal	dry	nails	Monkey
291	no tail	broad	longer	medium	diurnal	dry	nails	Ape
292	no tail	broad	longer	medium	diurnal	dry	nails	Ape
293	no tail	broad	longer	medium	diurnal	dry	nails	Ape
294	no tail	broad	longer	medium	diurnal	dry	nails	Ape
295	no tail	broad	longer	medium	diurnal	dry	nails	Ape
296	no tail	broad	longer	medium	diurnal	dry	nails	Ape
297	no tail	broad	longer	medium	diurnal	dry	nails	Ape
298	no tail	broad	longer	medium	diurnal	dry	nails	Ape
299	no tail	broad	longer	medium	diurnal	dry	nails	Ape
300	no tail	broad	longer	medium	diurnal	dry	nails	Ape
301	no tail	broad	longer	medium	diurnal	dry	nails	Ape
302	no tail	broad	longer	medium	diurnal	dry	nails	Ape
303	no tail	broad	longer	medium	diurnal	dry	nails	Ape
304	no tail	broad	longer	medium	diurnal	dry	nails	Ape
305	no tail	broad	longer	medium	diurnal	dry	nails	Ape
306	no tail	broad	longer	medium	diurnal	dry	nails	Ape
307	no tail	broad	longer	medium	diurnal	dry	nails	Ape
308	no tail	broad	longer	very large	diurnal	dry	nails	Ape
309	no tail	broad	longer	very large	diurnal	dry	nails	Ape
310	no tail	broad	longer	very large	diurnal	dry	nails	Ape
311	no tail	broad	longer	very large	diurnal	dry	nails	Ape
312	no tail	broad	longer	very large	diurnal	dry	nails	Ape
313	no tail	broad	longer	very large	diurnal	dry	nails	Ape
314	no tail	broad	longer	large	diurnal	dry	nails	Ape
315	no tail	broad	longer	large	diurnal	dry	nails	Ape

Example	Tail	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
316	no tail	broad	longer	large	diurnal	dry	nails	Ape
317	no tail	broad	longer	large	diurnal	dry	nails	Ape
318	no tail	broad	longer	large	diurnal	dry	nails	Ape

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Appendix B. Test Data

This appendix appears in its original form, without editorial change.

Example	Tails	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
1	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
2	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
3	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
4	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
5	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
6	tail	equal	shorter	very small	nocturnal	wet	claws	Prosimian
7	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
8	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
9	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
10	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
11	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
12	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
13	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
14	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
15	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
16	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
17	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
18	tail	equal	shorter	small	diurnal	wet	claws	Prosimian
19	tail	deep	shorter	small	nocturnal	wet	claws and nails	Prosimian
20	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
21	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
22	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
23	tail	equal	shorter	small	nocturnal	wet	claws and nails	Prosimian
24	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
25	tail	equal	shorter	very small	nocturnal	wet	claws and nails	Prosimian
26	tail	deep	shorter	small	diurnal	dry	claws	Monkey
27	tail	deep	shorter	small	diurnal	dry	claws	Monkey
28	tail	deep	shorter	small	diurnal	dry	claws	Monkey
29	tail	deep	shorter	small	diurnal	dry	claws	Monkey
30	tail	deep	shorter	small	diurnal	dry	claws	Monkey
31	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
32	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
33	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
34	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
35	tail	deep	shorter	medium	diurnal	dry	claws	Monkey
36	tail	deep	shorter	small	diurnal	dry	claws	Monkey
37	tail	deep	equal	small	diurnal	dry	nails	Monkey
38	tail	deep	equal	small	diurnal	dry	nails	Monkey
39	tail	deep	equal	medium	diurnal	dry	nails	Monkey
40	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey
41	tail	deep	shorter	medium	nocturnal	dry	nails	Monkey
42	tail	deep	equal	medium	diurnal	dry	nails	Monkey
43	tail	deep	equal	medium	diurnal	dry	nails	Monkey
44	tail	deep	equal	medium	diurnal	dry	nails	Monkey
45	tail	deep	equal	medium	diurnal	dry	nails	Monkey
46	tail	deep	equal	medium	diurnal	dry	nails	Monkey
47	tail	deep	equal	medium	diurnal	dry	nails	Monkey
48	tail	deep	equal	medium	diurnal	dry	nails	Monkey
49	tail	deep	equal	medium	diurnal	dry	nails	Monkey
50	tail	deep	equal	medium	diurnal	dry	nails	Monkey

Example	Tails	Chest Size	Arm-Leg Ratio	Size	Sleep Habits	Nose	Nails	Outcome
51	tail	deep	equal	medium	diurnal	dry	nails	Monkey
52	tail	deep	equal	large	diurnal	dry	nails	Monkey
53	tail	deep	equal	large	diurnal	dry	nails	Monkey
54	tail	deep	equal	large	diurnal	dry	nails	Monkey
55	tail	deep	equal	large	diurnal	dry	nails	Monkey
56	tail	deep	equal	medium	diurnal	dry	nails	Monkey
57	tail	deep	equal	medium	diurnal	dry	nails	Monkey
58	tail	deep	equal	medium	diurnal	dry	nails	Monkey
59	tail	deep	equal	medium	diurnal	dry	nails	Monkey
60	tail	deep	equal	medium	diurnal	dry	nails	Monkey
61	tail	deep	equal	medium	diurnal	dry	nails	Monkey
62	tail	deep	equal	medium	diurnal	dry	nails	Monkey
63	tail	deep	equal	medium	diurnal	dry	nails	Monkey
64	tail	deep	equal	medium	diurnal	dry	nails	Monkey
65	tail	deep	equal	medium	diurnal	dry	nails	Monkey
66	tail	deep	equal	medium	diurnal	dry	nails	Monkey
67	tail	deep	equal	medium	diurnal	dry	nails	Monkey
68	tail	deep	equal	medium	diurnal	dry	nails	Monkey
69	tail	deep	equal	medium	diurnal	dry	nails	Monkey
70	tail	deep	equal	medium	diurnal	dry	nails	Monkey
71	tail	deep	equal	medium	diurnal	dry	nails	Monkey
72	tail	deep	equal	medium	diurnal	dry	nails	Monkey
73	tail	deep	equal	medium	diurnal	dry	nails	Monkey
74	tail	deep	equal	medium	diurnal	dry	nails	Monkey
75	tail	deep	equal	medium	diurnal	dry	nails	Monkey
76	tail	broad	equal	large	diurnal	dry	nails	Monkey
77	tail	deep	equal	medium	diurnal	dry	nails	Monkey
78	tail	deep	equal	medium	diurnal	dry	nails	Monkey
79	tail	broad	equal	large	diurnal	dry	nails	Monkey
80	tail	broad	equal	large	diurnal	dry	nails	Monkey
81	tail	broad	equal	large	diurnal	dry	nails	Monkey
82	tail	broad	equal	large	diurnal	dry	nails	Monkey
83	tail	broad	equal	large	diurnal	dry	nails	Monkey
84	tail	broad	equal	large	diurnal	dry	nails	Monkey
85	tail	broad	equal	large	diurnal	dry	nails	Monkey
86	tail	deep	equal	medium	diurnal	dry	nails	Monkey
87	tail	deep	equal	medium	diurnal	dry	nails	Monkey
88	tail	deep	equal	medium	diurnal	dry	nails	Monkey
89	tail	deep	equal	medium	diurnal	dry	nails	Monkey
90	tail	deep	equal	medium	diurnal	dry	nails	Monkey
91	tail	deep	equal	medium	diurnal	dry	nails	Monkey
92	tail	deep	equal	medium	diurnal	dry	nails	Monkey
93	tail	deep	equal	medium	diurnal	dry	nails	Monkey
94	tail	deep	equal	medium	diurnal	dry	nails	Monkey
95	tail	deep	equal	medium	diurnal	dry	nails	Monkey
96	tail	deep	equal	medium	diurnal	dry	nails	Monkey
97	no tail	broad	longer	medium	diurnal	dry	nails	Ape
98	no tail	broad	longer	medium	diurnal	dry	nails	Ape
99	no tail	broad	longer	medium	diurnal	dry	nails	Ape
100	no tail	broad	longer	medium	diurnal	dry	nails	Ape
101	no tail	broad	longer	medium	diurnal	dry	nails	Ape
102	no tail	broad	longer	medium	diurnal	dry	nails	Ape
103	no tail	broad	longer	very large	diurnal	dry	nails	Ape
104	no tail	broad	longer	very large	diurnal	dry	nails	Ape
105	no tail	broad	longer	large	diurnal	dry	nails	Ape

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Appendix C. Classifier Performance Using Training Data and Test Data

Conjunctive Rule

SYNOPSIS: This class implements a single conjunctive rule learner that can predict for numeric and nominal class labels.

A rule consists of antecedents "AND"ed together and the consequent (class value) for the classification/regression. In this case, the consequent is the distribution of the available classes (or mean for a numeric value) in the dataset. If the test instance is not covered by this rule, then it's predicted using the default class distributions/value of the data not covered by the rule in the training data. This learner selects an antecedent by computing the Information Gain of each antecedent and prunes the generated rule using Reduced Error Pruning (REP) or simple pre-pruning based on the number of antecedents.

For classification, the Information of one antecedent is the weighted average of the entropies of both the data covered and not covered by the rule.
For regression, the Information is the weighted average of the mean-squared errors of both the data covered and not covered by the rule.

In pruning, weighted average of the accuracy rates on the pruning data is used for classification while the weighted average of the mean-squared errors on the pruning data is used for regression.

```
=== Run information ===

Scheme:       weka.classifiers.rules.ConjunctiveRule -N 3 -M 2.0 -P -1 -S 1
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===


Single conjunctive rule learner:
--------------------------------
(Nose = wet) => Outcome = Prosimian

Class distributions:
Covered by the rule:
Prosimian   Monkey      Ape
1           0           0

Not covered by the rule:
Prosimian   Monkey      Ape
0           0.888199    0.111801
```

```
Time taken to build model: 0.03 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         290               91.195  %
Incorrectly Classified Instances        28                8.805  %
Kappa statistic                          0.7956
Mean absolute error                      0.1023
Root mean squared error                  0.2279
Relative absolute error                 31.7043 %
Root relative squared error             56.8283 %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0.269      0.884     1         0.939      0.865    Monkey
  0         0          0         0         0          0.631    Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0  28   0 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances          96               91.4286 %
Incorrectly Classified Instances         9                8.5714 %
Kappa statistic                          0.7998
Mean absolute error                      0.1012
Root mean squared error                  0.2252
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0.265      0.888     1         0.94       0.868    Monkey
  0         0          0         0         0          0.63     Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
```

```
  0 71  0 |  b = Monkey
  0  9  0 |  c = Ape
```

JRip

SYNOPSIS: This class implements a propositional rule learner, Repeated Incremental Pruning to Produce Error Reduction (RIPPER), which was proposed by Cohen[1] as an optimized version of IREP.

The algorithm is briefly described as follows:

Initialize RS = {}, and for each class from the less prevalent one to the more frequent one, DO:

1. Building stage:
Repeat 1.1 and 1.2 until the description length (DL) of the ruleset and examples is 64 bits greater than the smallest DL met so far, or there are no positive examples, or the error rate >= 50%.

1.1. Grow phase:
Grow one rule by greedily adding antecedents (or conditions) to the rule until the rule is perfect (i.e., 100% accurate). The procedure tries every possible value of each attribute and selects the condition with highest information gain: p(log(p/t)-log(P/T)).

1.2. Prune phase:
Incrementally prune each rule and allow the pruning of any final sequences of the antecedents; The pruning metric is (p-n)/(p+n) -- but it's actually 2p/(p+n) -1, so in this implementation we simply use p/(p+n) (actually (p+1)/(p+n+2), thus if p+n is 0, it's 0.5).

2. Optimization stage:
after generating the initial ruleset {Ri}, generate and prune two variants of each rule Ri from randomized data using procedure 1.1 and 1.2. But one variant is generated from an empty rule while the other is generated by greedily adding antecedents to the original rule. Moreover, the pruning metric used here is (TP+TN)/(P+N).Then the smallest possible DL for each variant and the original rule is computed. The variant with the minimal DL is selected as the final representative of Ri in the ruleset. After all the rules in {Ri} have been examined and if there are still residual positives, more rules are generated based on the residual positives using Building Stage again.

3. Delete the rules from the ruleset that would increase the DL of the whole ruleset if it were in it, and add resultant ruleset to RS.
ENDDO

```
=== Run information ===

Scheme:       weka.classifiers.rules.JRip -F 3 -N 2.0 -O 2 -S 1
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
```

[1] Cohen W. Fast effective rule induction. Published in Proceedings of the 12th International Conference on Machine Learning; 1995 Jul 9–12; Lake Tahoe, CA. San Francisco (CA): Morgan Kaufmann; c1995. p. 115–123.

```
              Nails
              Outcome
Test mode:    evaluate on training data


=== Classifier model (full training set) ===

JRIP rules:
===========

(Tails = no_tail) => Outcome=Ape (28.0/0.0)
(Nose = wet) => Outcome=Prosimian (76.0/0.0)
 => Outcome=Monkey (214.0/0.0)

Number of Rules : 3


Time taken to build model: 0.07 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318               100      %
Incorrectly Classified Instances         0                 0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %
Root relative squared error              0      %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1        Prosimian
  1         0          1          1         1          1        Monkey
  1         0          1          1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105               100      %
Incorrectly Classified Instances         0                 0      %
```

```
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0         1           1         1          1        Prosimian
  1         0         1           1         1          1        Monkey
  1         0         1           1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

Non-Nested Generalized Exemplars

SYNOPSIS: Nearest-neighbor-like algorithm using non-nested generalized exemplars (which are hyper-rectangles that can be viewed as if-then rules). For more information, see Martin[2] and Roy.[3]

```
=== Run information ===

Scheme:       weka.classifiers.rules.NNge -G 5 -I 5
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===


NNGE classifier

Rules generated :
      class Ape IF : Tails in {no_tail} ^ Chest Size in {broad} ^ Arm-Leg
Ratio in {longer} ^ Size in {medium,large,very_large} ^ Sleep Habits in
{diurnal} ^ Nose in {dry} ^ Nails in {nails}  (28)
      class Monkey IF : Tails in {tail} ^ Chest Size in {deep,broad} ^ Arm-
```

[2] Martin B. Instance-based learning: Nearest neighbor with generalization. [dissertation]. [Hamilton (New Zealand)]: University of Waikato; 1995.

[3] Roy S. Nearest neighbor with generalization. [unpublished]. [Christchurch (New Zealand)]: University of Canterbury, 2002.

```
Leg Ratio in {shorter,equal} ^ Size in {small,medium,large} ^ Sleep Habits in
{nocturnal,diurnal} ^ Nose in {dry} ^ Nails in {claws,nails}  (214)
      class Prosimian IF : Tails in {tail} ^ Chest Size in {equal,deep} ^
Arm-Leg Ratio in {shorter} ^ Size in {very_small,small,medium} ^ Sleep Habits
in {nocturnal,diurnal} ^ Nose in {wet} ^ Nails in {claws,claws_and_nails}
(76)

Stat :

      class Prosimian : 1 exemplar(s) including 1 Hyperrectangle(s) and 0
Single(s).
      class Monkey : 1 exemplar(s) including 1 Hyperrectangle(s) and 0
Single(s).
      class Ape : 1 exemplar(s) including 1 Hyperrectangle(s) and 0
Single(s).

      Total : 3 exemplars(s) including 3 Hyperrectangle(s) and 0 Single(s).

      Feature weights : [0.42992832030968897 0.932127623605122
0.857511606191957 0.6290251428980856 0.6703867660729255 0.7933628469756622
0.6511518907599008]

Time taken to build model: 0.02 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %
Root relative squared error              0      %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1        Prosimian
  1         0          1          1         1          1        Monkey
  1         0          1          1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8
```

```
=== Summary ===

Correctly Classified Instances         105              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1        Prosimian
  1         0          1          1         1          1        Monkey
  1         0          1          1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

OneR Classifier

SYNOPSIS: Class for building and using a 1R classifier; in other words, uses the minimum-error attribute for prediction, discretizing numeric attributes. For more information, see Holte.[4]

```
=== Run information ===

Scheme:       weka.classifiers.rules.OneR -B 6
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Nose:
      wet   -> Prosimian
      dry   -> Monkey
(290/318 instances correct)

Time taken to build model: 0.01 seconds
```

[4] Holte RC. Very simple classification rules perform well on most commonly used datasets. Machine Learning. 1993;11:63–91.

```
=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         290               91.195  %
Incorrectly Classified Instances        28                8.805  %
Kappa statistic                          0.7956
Mean absolute error                      0.0587
Root mean squared error                  0.2423
Relative absolute error                 18.1929 %

Root relative squared error             60.4273 %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0         1          1         1          1        Prosimian
  1         0.269     0.884      1         0.939      0.865    Monkey
  0         0         0          0         0          0.5      Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0  28   0 |   c = Ape

=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances          96               91.4286 %
Incorrectly Classified Instances         9                8.5714 %
Kappa statistic                          0.7998
Mean absolute error                      0.0571
Root mean squared error                  0.239
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0         1          1         1          1        Prosimian
  1         0.265     0.888      1         0.94       0.868    Monkey
  0         0         0          0         0          0.5      Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  9  0 |  c = Ape
```

PART Decision List

SYNOPSIS: Class for generating a PART decision list. Uses separate-and-conquer. Builds a partial C4.5 decision tree in each iteration and makes the "best" leaf into a rule.

For more information, see: Frank.[5]

```
=== Run information ===

Scheme:       weka.classifiers.rules.PART -M 2 -C 0.25 -Q 1
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

PART decision list
------------------

Nose = dry AND
Tails = tail: Monkey (214.0)

Tails = tail: Prosimian (76.0)

: Ape (28.0)

Number of Rules  :      3


Time taken to build model: 0.02 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %
Root relative squared error              0      %
Total Number of Instances              318

=== Detailed Accuracy By Class ===
```

[5] Frank E, Witten IH. Generating accurate rule sets without global optimization. Published in 15th International Conference on Machine Learning; 1998 Jul 24–27; Madison, WI. San Mateo (CA): Morgan Kaufmann; c1998. p. 144–151.

```
TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey

   0   0  28 |   c = Ape

=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

Prism Classifier

SYNOPSIS
Class for building and using a PRISM rule set for classification. Can only deal with nominal attributes. Can't deal with missing values. Doesn't do any pruning.

For more information, see Cendrowska.[6]

```
=== Run information ===

Scheme:       weka.classifiers.rules.Prism
Relation:     training data
Instances:    318
```

[6] Cendrowska J. PRISM: An algorithm for inducing modular rules. International Journal of Man-Machine Studies. 1987;27(4):349–370.

```
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome

Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Prism rules
----------
If Nose = wet then Prosimian
If Arm-Leg Ratio = equal then Monkey
If Chest Size = deep
   and Nose = dry then Monkey
If Tails = no_tail then Ape

Time taken to build model: 0.02 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %
Root relative squared error              0      %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8
```

```
=== Summary ===

Correctly Classified Instances         105              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1        Prosimian
  1         0          1          1         1          1        Monkey
  1         0          1          1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

RIpple-DOwn Rule learner (RIDOR)

SYNOPSIS: The implementation of a RIpple-DOwn Rule learner. It generates a default rule first and then the exceptions for the default rule with the least (weighted) error rate. Then it generates the "best" exceptions for each exception and iterates until pure. Thus it performs a tree-like expansion of exceptions.The exceptions are a set of rules that predict classes other than the default. IREP is used to generate the exceptions.

For more information about Ripple-Down Rules, see Gaines and Compton.[7]

```
=== Run information ===

Scheme:       weka.classifiers.rules.Ridor -F 3 -S 1 -N 2.0
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

RIpple DOwn Rule Learner(Ridor) rules
--------------------------------------
```

[7]Gaines BR, Compton P. Induction of ripple-down rules applied to modeling large databases. Joint Intelligent Inference Systems. 1995;5(3):211–228.

```
Outcome = Monkey  (318.0/104.0)
           Except (Nose = wet) => Outcome = Prosimian  (50.0/0.0) [26.0/0.0]
           Except (Chest Size = broad) and (Arm-Leg Ratio = longer) =>
Outcome = Ape  (19.0/0.0) [9.0/0.0]

Total number of rules (incl. the default rule): 3

Time taken to build model: 0.04 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %
Root relative squared error              0      %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian

  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Total Number of Instances              105
```

```
=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1        Prosimian
  1         0          1          1         1          1        Monkey
  1         0          1          1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

ZeroR Classifier

SYNOPSIS: Class for building and using a 0-R classifier. Predicts the mean (for a numeric class) or the mode (for a nominal class).

```
=== Run information ===

Scheme:       weka.classifiers.rules.ZeroR
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio

              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

ZeroR predicts class value: Monkey

Time taken to build model: 0 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         214               67.2956 %
Incorrectly Classified Instances       104               32.7044 %
Kappa statistic                          0
Mean absolute error                      0.3227
Root mean squared error                  0.4009
Relative absolute error                100      %
Root relative squared error            100      %
Total Number of Instances              318
```

```
=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  0         0          0         0         0          0.5      Prosimian
  1         1          0.673     1         0.805      0.5      Monkey
  0         0          0         0         0          0.5      Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
   0  76   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0  28   0 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances          71               67.619  %
Incorrectly Classified Instances        34               32.381  %
Kappa statistic                          0
Mean absolute error                      0.3215
Root mean squared error                  0.3995
Total Number of Instances              105

=== Detailed Accuracy By Class ===
TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  0         0          0         0         0          0.5      Prosimian
  1         1          0.676     1         0.807      0.5      Monkey
  0         0          0         0         0          0.5      Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
  0 25  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  9  0 |  c = Ape
```

Decision Stump

SYNOPSIS: Class for building and using a decision stump. Usually used in conjunction with a boosting algorithm. Does regression (based on mean-squared error) or classification (based on entropy). Missing is treated as a separate value.

```
=== Run information ===

Scheme:       weka.classifiers.trees.DecisionStump
Relation:     training data
Instances:    318
Attributes:   8
              Tails
```

```
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Decision Stump

Classifications

Nose = wet : Prosimian
Nose != wet : Monkey
Nose is missing : Monkey

Class distributions

Nose = wet
Prosimian   Monkey      Ape
1.0   0.0   0.0
Nose != wet
Prosimian   Monkey      Ape
0.0   0.8842975206611571      0.11570247933884298
Nose is missing
Prosimian   Monkey      Ape
0.2389937106918239      0.6729559748427673      0.0880503144654088


Time taken to build model: 0.01 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         290               91.195  %
Incorrectly Classified Instances        28                8.805  %
Kappa statistic                          0.7956
Mean absolute error                      0.1038
Root mean squared error                  0.2278
Relative absolute error                 32.1758 %
Root relative squared error             56.824  %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0.269      0.884     1         0.939      0.865    Monkey
  0         0          0         0         0          0.631    Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
```

```
   0 214   0 |   b = Monkey
   0  28   0 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances          96               91.4286 %
Incorrectly Classified Instances         9                8.5714 %
Kappa statistic                          0.7998
Mean absolute error                      0.1027
Root mean squared error                  0.2252
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0.265      0.888     1         0.94       0.868    Monkey
  0         0          0         0         0          0.63     Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  9  0 |  c = Ape
```

RandomTree

SYNOPSIS: Class for constructing a tree that considers K randomly chosen attributes at each node. RandomTree performs no pruning.

```
=== Run information ===

Scheme:       weka.classifiers.trees.RandomTree -K 1 -M 1.0 -S 1
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data
```

```
=== Classifier model (full training set) ===


RandomTree
==========

Arm-Leg Ratio = shorter
|   Sleep Habits = nocturnal
|   |   Nose = wet : Prosimian (75/0)
|   |   Nose = dry : Monkey (6/0)
|   Sleep Habits = diurnal
|   |   Nose = wet : Prosimian (1/0)
|   |   Nose = dry : Monkey (32/0)
Arm-Leg Ratio = equal : Monkey (176/0)
Arm-Leg Ratio = longer : Ape (28/0)

Size of the tree : 10

Time taken to build model: 0.01 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318                100      %
Incorrectly Classified Instances         0                  0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %

Root relative squared error              0      %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8
```

```
=== Summary ===

Correctly Classified Instances         105               100      %
Incorrectly Classified Instances         0                 0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1        Prosimian
  1         0          1          1         1          1        Monkey
  1         0          1          1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

Bayes Network Classifier

SYNOPSIS: Bayes Network learning using various search algorithms and quality measures. Base class for a Bayes Network classifier. Provides datastructures (network structure, conditional probability distributions, etc.) and facilities common to Bayes Network learning algorithms like K2 and B.
For more information see:

http://www.cs.waikato.ac.nz/~remco/weka.pdf

```
=== Run information ===

Scheme:       weka.classifiers.bayes.BayesNet -D -Q
weka.classifiers.bayes.net.search.local.K2 -- -P 1 -S BAYES -E
weka.classifiers.bayes.net.estimate.SimpleEstimator -- -A 0.5
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Bayes Network Classifier
not using ADTree
#attributes=8 #classindex=7
Network structure (nodes followed by parents)
```

```
Tails(2): Outcome
Chest Size(3): Outcome
Arm-Leg Ratio(3): Outcome
Size(5): Outcome
Sleep Habits(2): Outcome
Nose(2): Outcome
Nails(3): Outcome
Outcome(3):
LogScore Bayes: -966.7300307896232
LogScore BDeu: -1041.4313183663835
LogScore MDL: -1081.2851986418486
LogScore ENTROPY: -963.163145294855
LogScore AIC: -1004.163145294855


Time taken to build model: 0.02 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318               100      %
Incorrectly Classified Instances         0                 0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0.0001
Relative absolute error                  0.0098 %
Root relative squared error              0.0286 %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105               100      %
Incorrectly Classified Instances         0                 0      %
Kappa statistic                          1
Mean absolute error                      0
```

```
Root mean squared error                    0.0001
Total Number of Instances                105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

Naive Bayes Classifier

SYNOPSIS: Class for a Naive Bayes classifier using estimator classes. Numeric estimator precision values are chosen based on analysis of the training data. For this reason, the classifier is not an UpdateableClassifier (which in typical usage are initialized with zero training instances)—if you need the UpdateableClassifier functionality, use the NaiveBayesUpdateable classifier. The NaiveBayesUpdateable classifier will use a default precision of 0.1 for numeric attributes when buildClassifier is called with zero training instances.

For more information on Naive Bayes classifiers, see John.[8]

```
=== Run information ===

Scheme:       weka.classifiers.bayes.NaiveBayes
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Naive Bayes Classifier

Class Prosimian: Prior probability = 0.24

Tails:  Discrete Estimator. Counts =  77 1  (Total = 78)
Chest Size:  Discrete Estimator. Counts =  73 5 1  (Total = 79)
Arm-Leg Ratio:  Discrete Estimator. Counts =  77 1 1  (Total = 79)
```

[8] John GH, Langley P. Estimating continuous distributions in Bayesian classifiers. Published in 11th Conference on Uncertainty in Artificial Intelligence; 1995 Aug 18–20; Montreal, Quebec, Canada. San Mateo (CA): Morgan Kaufmann; c.1995. p. 338–345.

```
Size:  Discrete Estimator. Counts =  27 50 2 1 1  (Total = 81)
Sleep Habits:  Discrete Estimator. Counts =  76 2  (Total = 78)
Nose:  Discrete Estimator. Counts =  77 1  (Total = 78)
Nails:  Discrete Estimator. Counts =  22 56 1  (Total = 79)


Class Monkey: Prior probability = 0.67

Tails:  Discrete Estimator. Counts =  215 1  (Total = 216)
Chest Size:  Discrete Estimator. Counts =  1 190 26  (Total = 217)
Arm-Leg Ratio:  Discrete Estimator. Counts =  39 177 1  (Total = 217)
Size:  Discrete Estimator. Counts =  1 25 156 36 1  (Total = 219)
Sleep Habits:  Discrete Estimator. Counts =  7 209  (Total = 216)
Nose:  Discrete Estimator. Counts =  1 215  (Total = 216)
Nails:  Discrete Estimator. Counts =  33 1 183  (Total = 217)


Class Ape: Prior probability = 0.09

Tails:  Discrete Estimator. Counts =  1 29  (Total = 30)
Chest Size:  Discrete Estimator. Counts =  1 1 29  (Total = 31)
Arm-Leg Ratio:  Discrete Estimator. Counts =  1 1 29  (Total = 31)
Size:  Discrete Estimator. Counts =  1 1 18 6 7  (Total = 33)
Sleep Habits:  Discrete Estimator. Counts =  1 29  (Total = 30)
Nose:  Discrete Estimator. Counts =  1 29  (Total = 30)
Nails:  Discrete Estimator. Counts =  1 1 29  (Total = 31)


Time taken to build model: 0 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0.0001
Root mean squared error                  0.0004
Relative absolute error                  0.0327 %
Root relative squared error              0.0961 %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape
```

```
=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0.0001
Root mean squared error                  0.0004
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian

  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

Logistic Function

SYNOPSIS: Class for building and using a multinomial logistic regression model with a ridge estimator.

There are some modifications, however, compared to the paper of le Cessie and van Houwelingen[9] :

If there are k classes for n instances with m attributes, the parameter matrix B to be calculated will be an m*(k-1) matrix.

The probability for class j with the exception of the last class is

Pj(Xi) = exp(XiBj)/((sum[j=1..(k-1)]exp(Xi*Bj))+1)

The last class has probability

1-(sum[j=1..(k-1)]Pj(Xi))
= 1/((sum[j=1..(k-1)]exp(Xi*Bj))+1)

The (negative) multinomial log-likelihood is thus:

L = -sum[i=1..n]{
sum[j=1..(k-1)](Yij * ln(Pj(Xi)))
+(1 - (sum[j=1..(k-1)]Yij))
* ln(1 - sum[j=1..(k-1)]Pj(Xi))

[9] le Cessie S, van Houwelingen JC. Ridge estimators in logistic regression. Applied Statistics. 1992;41(1):191–201.

} + ridge * (B^2)

To find the matrix B for which L is minimised, a Quasi-Newton Method is used to search for the optimized values of the m*(k-1) variables. Before we use the optimization procedure, we 'squeeze' the matrix B into a m*(k-1) vector. For details of the optimization procedure, please check weka.core.Optimization class.

Although original Logistic Regression does not deal with instance weights, we modify the algorithm a little bit to handle the instance weights.

For more information see le Cessie, et al. (1992).

```
=== Run information ===

Scheme:       weka.classifiers.functions.Logistic -R 1.0E-8 -M -1
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Logistic Regression with ridge parameter of 1.0E-8
Coefficients...
Variable      Coeff.
       1      -9.9896     -32.249
       2       5.5378      -7.7552
       3      -1.6877       3.6214
       4      -4.0848       3.5597
       5      -5.814        6.7355
       6       8.6558       4.2102
       7      -9.9896     -32.249
       8      -0.9676      -4.5626
       9      -4.0745       2.2912
      10       2.8524       0.2208
      11       0.6734      -5.8543
      12       0.6297      28.4311
      13      -0.6473       3.3401
      14     -39.8208      38.7989
      15      -5.4798       9.456
      16      -1.9953      -8.5087
      17       4.666       -0.4291
Intercept     31.9474   -24.6568

Odds Ratios...
Variable         O.R.
       1       0             0
       2     254.1236       0.0004
       3       0.185       37.3885
```

```
       4       0.0168      35.1512
       5       0.003      841.7932
       6    5743.3444      67.3675
       7       0            0
       8       0.38         0.0104
       9       0.017        9.8864
      10      17.3287       1.2471
      11       1.9608       0.0029
      12       1.8771 2.225633855741724E12
      13       0.5234      28.2217
      14       0       7.0819733759335056E16
      15       0.0042   12785.2051
      16       0.136        0.0002
      17     106.2759       0.6511


Time taken to build model: 0.26 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318              100      %

Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Relative absolute error                  0      %
Root relative squared error              0      %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1           1        Prosimian
  1         0          1         1         1           1        Monkey
  1         0          1         1         1           1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105              100      %
Incorrectly Classified Instances         0                0      %
```

```
Kappa statistic                          1
Mean absolute error                      0
Root mean squared error                  0
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1        Prosimian
  1         0          1          1         1          1        Monkey
  1         0          1          1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

Multilayer Perceptron Function

SYNOPSIS: A Classifier that uses back propagation to classify instances. This network can be built by hand, created by an algorithm, or both. The network can also be monitored and modified during training time. The nodes in this network are all sigmoid (except for when the class is numeric, in which case the output nodes become unthresholded linear units).

```
=== Run information ===

Scheme:       weka.classifiers.functions.MultilayerPerceptron -L 0.3 -M 0.2 -
N 500 -V 0 -S 0 -E 20 -H a
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Sigmoid Node 0
    Inputs    Weights
    Threshold    1.3012106967650572
    Node 3    -0.15071256073059616
    Node 4    3.5665363147322036
    Node 5    -1.8776292168358872
    Node 6    -0.9832971903489884
    Node 7    -0.9279063157966061
    Node 8    -0.5714146675677457
    Node 9    -2.3367795016783064
    Node 10    -0.8921068780522895
```

```
    Node 11    -2.3980561283521236
    Node 12    0.905513496995433
Sigmoid Node 1
    Inputs    Weights
    Threshold    -4.591049245230357
    Node 3    1.6087556954669266
    Node 4    -2.3043762155765473
    Node 5    -0.41420818708580687
    Node 6    2.7632927457519703
    Node 7    1.9784174901212792
    Node 8    2.1694662343240463
    Node 9    0.4527091278606214
    Node 10    2.603402907190577
    Node 11    -0.6199390532758464
    Node 12    0.5846311391177982
Sigmoid Node 2
    Inputs    Weights
    Threshold    0.3271651330385988
    Node 3    -1.9851678817289902
    Node 4    -3.039920034682528
    Node 5    1.4622001852234694
    Node 6    -1.9047348840695637
    Node 7    -1.2867292171442253
    Node 8    -1.9403459222178623
    Node 9    1.2612518617806905
    Node 10    -1.909182187805521
    Node 11    2.192002256276242
    Node 12    -2.6010184279203687
Sigmoid Node 3
    Inputs    Weights
    Threshold    -0.22868683815479499
    Attrib Tails    -0.8706728859494896
    Attrib Chest Size=equal    -0.0448688366456124
    Attrib Chest Size=deep    0.7324142188639325
    Attrib Chest Size=broad    -0.38996975745642043
    Attrib Arm-Leg Ratio=shorter    0.029756656298761813
    Attrib Arm-Leg Ratio=equal    1.0638679287290083
    Attrib Arm-Leg Ratio=longer    -0.8998606930210152
    Attrib Size=very_small    -0.04307226810555337
    Attrib Size=small    0.04110750389722187
    Attrib Size=medium    0.2616382076998021
    Attrib Size=large    0.4738579902658915
    Attrib Size=very_large    0.06414998512816784
    Attrib Sleep Habits    0.24063898379633883
    Attrib Nose    0.46129527392087954
    Attrib Nails=claws    0.23387049471950103
    Attrib Nails=claws_and_nails    -0.1835628828345494
    Attrib Nails=nails    0.15821876113733002
Sigmoid Node 4
    Inputs    Weights
    Threshold    -0.024454725426920874
    Attrib Tails    -0.40528918682444504
    Attrib Chest Size=equal    0.8616469066329208
    Attrib Chest Size=deep    -0.4550516047893378
    Attrib Chest Size=broad    -0.3635436102502261
    Attrib Arm-Leg Ratio=shorter    0.2727172286177625
    Attrib Arm-Leg Ratio=equal    0.24719466201347665
```

```
    Attrib Arm-Leg Ratio=longer    -0.34887607805371423
    Attrib Size=very_small    0.37507041507268357
    Attrib Size=small    0.21197841440576198
    Attrib Size=medium    -0.3267426356024103
    Attrib Size=large    0.03617658165743892
    Attrib Size=very_large    -0.038110161865268125
    Attrib Sleep Habits    -0.7437405467706905
    Attrib Nose    -1.0707113102263948
    Attrib Nails=claws    -0.18177186021291622
    Attrib Nails=claws_and_nails    0.7137651410337604
    Attrib Nails=nails    -0.47167319926321416
Sigmoid Node 5
    Inputs    Weights
    Threshold    0.03857162395900296
    Attrib Tails    0.18601616251264821
    Attrib Chest Size=equal    -0.5748860630358589
    Attrib Chest Size=deep    0.35350457393749635
    Attrib Chest Size=broad    0.2275878584849743
    Attrib Arm-Leg Ratio=shorter    -0.4484319571515167
    Attrib Arm-Leg Ratio=equal    0.1782546520944032
    Attrib Arm-Leg Ratio=longer    0.17832927445606872
    Attrib Size=very_small    -0.2569496693896704
    Attrib Size=small    -0.24253501956668033
    Attrib Size=medium    0.2553808277244045
    Attrib Size=large    0.11587673467161907
    Attrib Size=very_large    0.09867814113033117
    Attrib Sleep Habits    0.6500393525438719
    Attrib Nose    0.7161299822285648
    Attrib Nails=claws    0.011965781339222407
    Attrib Nails=claws_and_nails    -0.5104637106198827
    Attrib Nails=nails    0.5089780614365306
Sigmoid Node 6
    Inputs    Weights
    Threshold    -0.4407940458466727
    Attrib Tails    -0.8768496017447188
    Attrib Chest Size=equal    -0.2993926991762047
    Attrib Chest Size=deep    1.1793734360421806
    Attrib Chest Size=broad    -0.3687176505825691
    Attrib Arm-Leg Ratio=shorter    0.010619147442384345
    Attrib Arm-Leg Ratio=equal    1.3625094153376334
    Attrib Arm-Leg Ratio=longer    -0.902362677180076
    Attrib Size=very_small    0.032285101994000004
    Attrib Size=small    -0.025119315809754093
    Attrib Size=medium    0.47299591823879933
    Attrib Size=large    0.6695639364535472
    Attrib Size=very_large    0.24581818084348261
    Attrib Sleep Habits    0.4179863681333151
    Attrib Nose    0.9087377781035069
    Attrib Nails=claws    0.5949414111242165
    Attrib Nails=claws_and_nails    -0.4480911911524315
    Attrib Nails=nails    0.3408618390285688
Sigmoid Node 7
    Inputs    Weights
    Threshold    -0.42889286121398607
    Attrib Tails    -0.7500162424221544
    Attrib Chest Size=equal    -0.31209774601128293
    Attrib Chest Size=deep    1.0178835714822518
```

```
    Attrib Chest Size=broad    -0.349325471643971
    Attrib Arm-Leg Ratio=shorter    0.00598709422663726
    Attrib Arm-Leg Ratio=equal    1.1502510722402293
    Attrib Arm-Leg Ratio=longer    -0.6871970988951007
    Attrib Size=very_small    0.04678787258870635
    Attrib Size=small    0.0035010585112271527
    Attrib Size=medium    0.41566061117006115
    Attrib Size=large    0.5711758656053683
    Attrib Size=very_large    0.20456425031913883
    Attrib Sleep Habits    0.42634221939740335
    Attrib Nose    0.7094277002076911
    Attrib Nails=claws    0.48645528059175724
    Attrib Nails=claws_and_nails    -0.3870580834621535
    Attrib Nails=nails    0.24700015118118937
Sigmoid Node 8
    Inputs    Weights
    Threshold    -0.36941389560302135
    Attrib Tails    -0.8453340218650478
    Attrib Chest Size=equal    -0.202256639703651
    Attrib Chest Size=deep    0.9614405088301267
    Attrib Chest Size=broad    -0.3767362058390345
    Attrib Arm-Leg Ratio=shorter    0.0027711478149257426
    Attrib Arm-Leg Ratio=equal    1.2519135151823058
    Attrib Arm-Leg Ratio=longer    -0.8831122803646008
    Attrib Size=very_small    0.05449735546384061
    Attrib Size=small    -0.028370360938928713
    Attrib Size=medium    0.3920810595802077
    Attrib Size=large    0.5905557583568866
    Attrib Size=very_large    0.18816156653425414
    Attrib Sleep Habits    0.3548643253823544
    Attrib Nose    0.7561898134279856
    Attrib Nails=claws    0.45810266923853177
    Attrib Nails=claws_and_nails    -0.3142752996651219
    Attrib Nails=nails    0.2979108556784972
Sigmoid Node 9
    Inputs    Weights
    Threshold    0.03820276970562375
    Attrib Tails    -0.01123011608833772
    Attrib Chest Size=equal    -0.756261241901086
    Attrib Chest Size=deep    0.6316286927466682
    Attrib Chest Size=broad    0.13943799252273947
    Attrib Arm-Leg Ratio=shorter    -0.35428175030019193
    Attrib Arm-Leg Ratio=equal    0.4455810613680112
    Attrib Arm-Leg Ratio=longer    -0.025092368483231424
    Attrib Size=very_small    -0.34397155585794514
    Attrib Size=small    -0.2640088488200906
    Attrib Size=medium    0.3537371978616421
    Attrib Size=large    0.1375478167250311
    Attrib Size=very_large    0.10486496035855912
    Attrib Sleep Habits    0.7984657225897356
    Attrib Nose    0.9878054437272061
    Attrib Nails=claws    0.17109204698447372
    Attrib Nails=claws_and_nails    -0.6646202815697826
    Attrib Nails=nails    0.505596379678196
Sigmoid Node 10
    Inputs    Weights
    Threshold    -0.4279610177424282
```

```
    Attrib Tails    -0.8555043686551411
    Attrib Chest Size=equal    -0.31896739070126745
    Attrib Chest Size=deep    1.128377494236569
    Attrib Chest Size=broad    -0.39480327170169116
    Attrib Arm-Leg Ratio=shorter    0.05974792636865227
    Attrib Arm-Leg Ratio=equal    1.3239447319338782
    Attrib Arm-Leg Ratio=longer    -0.8997271829758088
    Attrib Size=very_small    0.04605954948148706
    Attrib Size=small    -0.061164288925263384
    Attrib Size=medium    0.4436682083935165
    Attrib Size=large    0.6725321321722918
    Attrib Size=very_large    0.27823415177038313
    Attrib Sleep Habits    0.4608065164708468
    Attrib Nose    0.8265080080813495
    Attrib Nails=claws    0.5572608055533798
    Attrib Nails=claws_and_nails    -0.4192955619948751
    Attrib Nails=nails    0.3536017576701385
Sigmoid Node 11
    Inputs    Weights
    Threshold    -0.006815893586848453
    Attrib Tails    0.2995164285845169
    Attrib Chest Size=equal    -0.6590786212943847
    Attrib Chest Size=deep    0.3450280887297489
    Attrib Chest Size=broad    0.33332317704047076
    Attrib Arm-Leg Ratio=shorter    -0.5028573164224909
    Attrib Arm-Leg Ratio=equal    0.18563330908873857
    Attrib Arm-Leg Ratio=longer    0.26434020567495936
    Attrib Size=very_small    -0.2653476914665689
    Attrib Size=small    -0.24983172019176017
    Attrib Size=medium    0.2107053119125198
    Attrib Size=large    0.07724611111975499
    Attrib Size=very_large    0.0397859326235434
    Attrib Sleep Habits    0.7510339172304787
    Attrib Nose    0.8023427967140727
    Attrib Nails=claws    0.0034222325005445926
    Attrib Nails=claws_and_nails    -0.49747421996597047
    Attrib Nails=nails    0.4772318405942686
Sigmoid Node 12
    Inputs    Weights
    Threshold    0.1375267582521297
    Attrib Tails    -1.0559935859455922
    Attrib Chest Size=equal    0.03197272950039177
    Attrib Chest Size=deep    0.3299648939964681
    Attrib Chest Size=broad    -0.6484497712771019
    Attrib Arm-Leg Ratio=shorter    0.28535546672457196
    Attrib Arm-Leg Ratio=equal    0.6735763642494895
    Attrib Arm-Leg Ratio=longer    -1.1306099287755755
    Attrib Size=very_small    -0.1339336694249159
    Attrib Size=small    0.07538523227217672
    Attrib Size=medium    -0.19396330812424623
    Attrib Size=large    0.025155585757356783
    Attrib Size=very_large    -0.32484897247477534
    Attrib Sleep Habits    -0.09150058326118905
    Attrib Nose    0.0044122906645481024
    Attrib Nails=claws    -0.031248739211253762
    Attrib Nails=claws_and_nails    0.031606951232683596
    Attrib Nails=nails    -0.19904197135905405
```

```
Class Prosimian
    Input
    Node 0
Class Monkey
    Input
    Node 1
Class Ape
    Input
    Node 2


Time taken to build model: 10.12 seconds

=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         318               100      %
Incorrectly Classified Instances         0                 0      %
Kappa statistic                          1
Mean absolute error                      0.003
Root mean squared error                  0.0041
Relative absolute error                  0.9363 %

Root relative squared error              1.0128 %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape

=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105               100      %
Incorrectly Classified Instances         0                 0      %
Kappa statistic                          1
Mean absolute error                      0.003
Root mean squared error                  0.004
Total Number of Instances              105
```

```
=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1          1         1          1         Prosimian
  1         0          1          1         1          1         Monkey
  1         0          1          1         1          1         Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

Locally Weighted Learning (LWL) Classifier

SYNOPSIS: Locally weighted learning. It uses an instance-based algorithm to assign instance weights, which are then used by a specified WeightedInstancesHandler. Can do classification (e.g. using naive Bayes) or regression (e.g. using linear regression).

For more info, see Frank[10] and Atkeson.[11]

```
=== Run information ===

Scheme:       weka.classifiers.lazy.LWL -U 0 -K -1 -A
"weka.core.neighboursearch.LinearNNSearch -A weka.core.EuclideanDistance" -W
weka.classifiers.trees.DecisionStump
Relation:     training data
Instances:    318
Attributes:   8
              Tails
              Chest Size
              Arm-Leg Ratio
              Size
              Sleep Habits
              Nose
              Nails
              Outcome
Test mode:    evaluate on training data

=== Classifier model (full training set) ===

Locally weighted learning
===========================
Using classifier: weka.classifiers.trees.DecisionStump
Using linear weighting kernels
Using all neighbours
Time taken to build model: 0.01 seconds

=== Evaluation on training set ===
=== Summary ===
```

[10] Frank E, Hall M, Pfahringer B. Locally Weighted Naive Bayes. Published In: 19th Conference in Uncertainty in Artificial Intelligence; 2003 Aug 7–10; Acapulco, NM. San Francisco (CA): Morgan Kaufmann; c2003. p. 249–256.

[11] Atkeson C, Moore A, Schaal S. Locally weighted learning. AI Review. 1997;11(1–5):11–73.

```
Correctly Classified Instances         318              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0.0027
Root mean squared error                  0.0072
Relative absolute error                  0.8347 %
Root relative squared error              1.7957 %
Total Number of Instances              318

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

   a   b   c   <-- classified as
  76   0   0 |   a = Prosimian
   0 214   0 |   b = Monkey
   0   0  28 |   c = Ape


=== Re-evaluation on test set ===

User supplied test set
Relation:     test data
Instances:    105
Attributes:   8

=== Summary ===

Correctly Classified Instances         105              100      %
Incorrectly Classified Instances         0                0      %
Kappa statistic                          1
Mean absolute error                      0.0025
Root mean squared error                  0.0067
Total Number of Instances              105

=== Detailed Accuracy By Class ===

TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
  1         0          1         1         1          1        Prosimian
  1         0          1         1         1          1        Monkey
  1         0          1         1         1          1        Ape

=== Confusion Matrix ===

  a  b  c   <-- classified as
 25  0  0 |  a = Prosimian
  0 71  0 |  b = Monkey
  0  0  9 |  c = Ape
```

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